CALIPSO, CloudSat, CERES, and MODIS merged A-train data set

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Outline of this talk

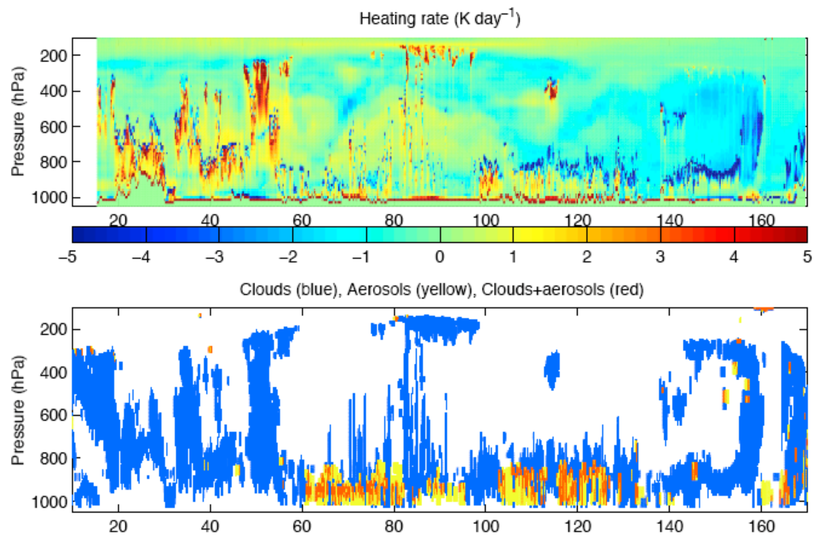
- Brief descriptions of the C3M data product
- How C3M is used in NASA and by others
- Improvements for the next version
- Spectral radiance computations

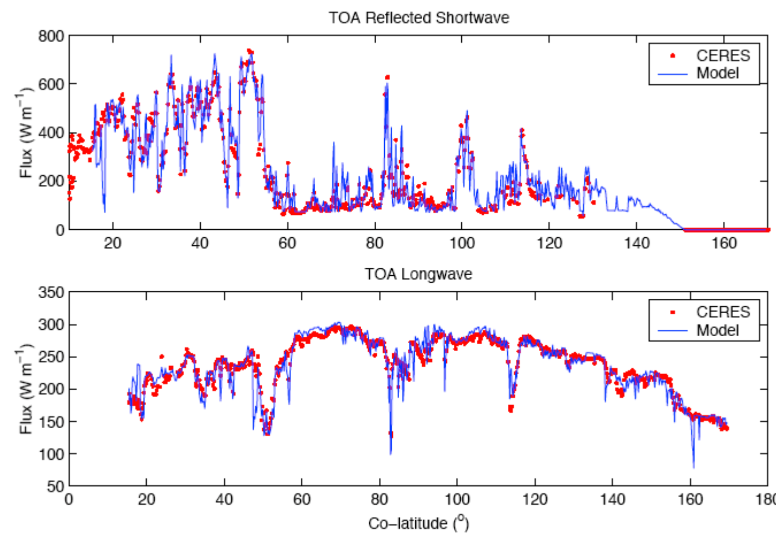
C3M (CCCM) product

- Contains:

1. Merged CALIPSO, CloudSat derived clouds, CERES TOA radiative flux (SW, LW, and WN), MODIS (CERES_ST) derived cloud properties both along CALIPSO-CloudSat ground-track and over the whole CERES footprint,
2. MODIS derived cloud properties by an enhanced cloud algorithm,
3. CALIPSO and MODIS derived aerosol properties
4. Vertical radiative flux profiles computed with CALIPSO, CloudSat, and MODIS derived cloud properties.

- 44 months of data (July 2006 through 2010) are available from http://eosweb.larc.nasa.gov/PRODOCS/ceres-news/table_ceres-news.html





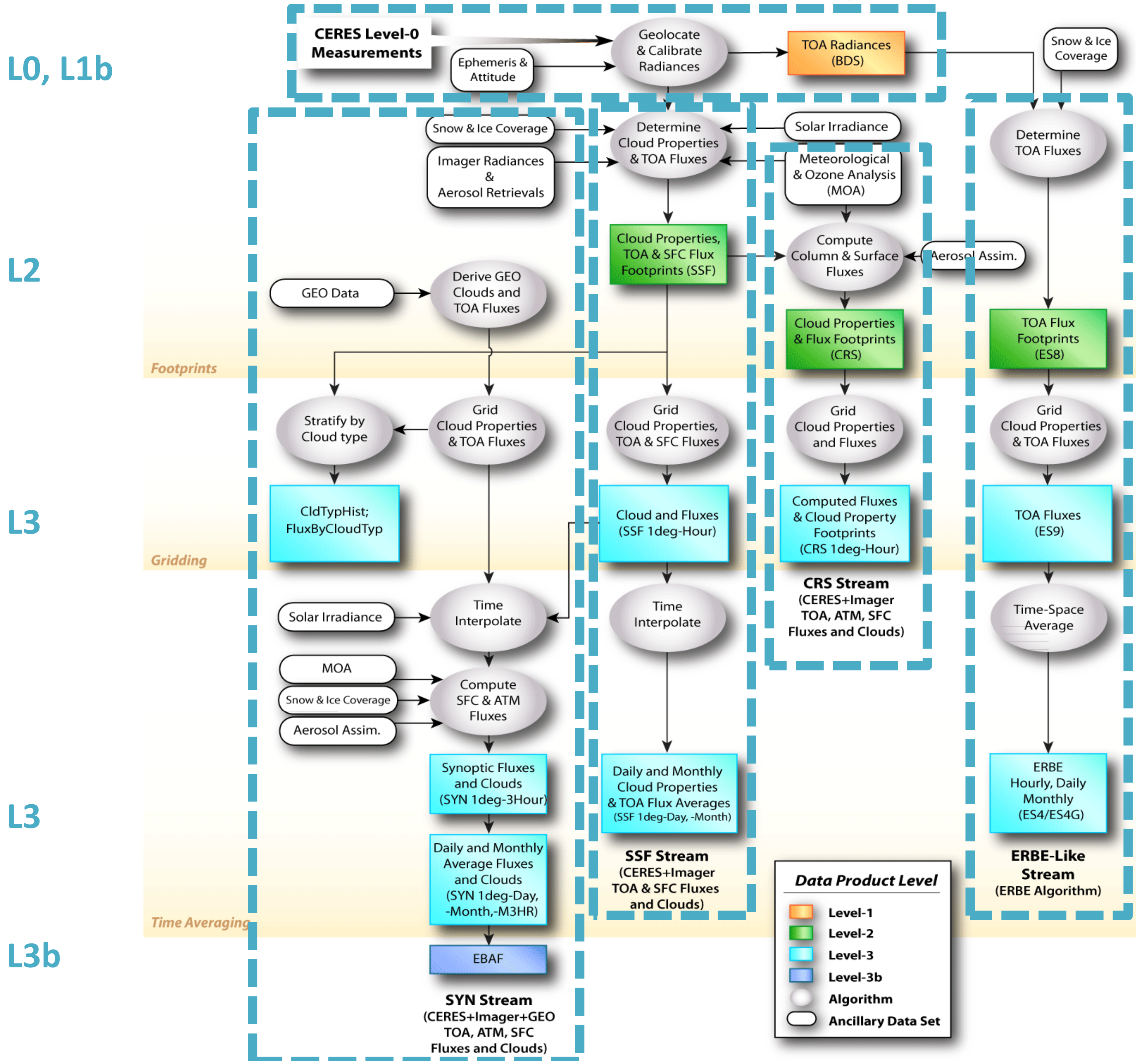
Outline

- Merging process
- Data set provided to Howard
- Some results relevant to EarthCARE

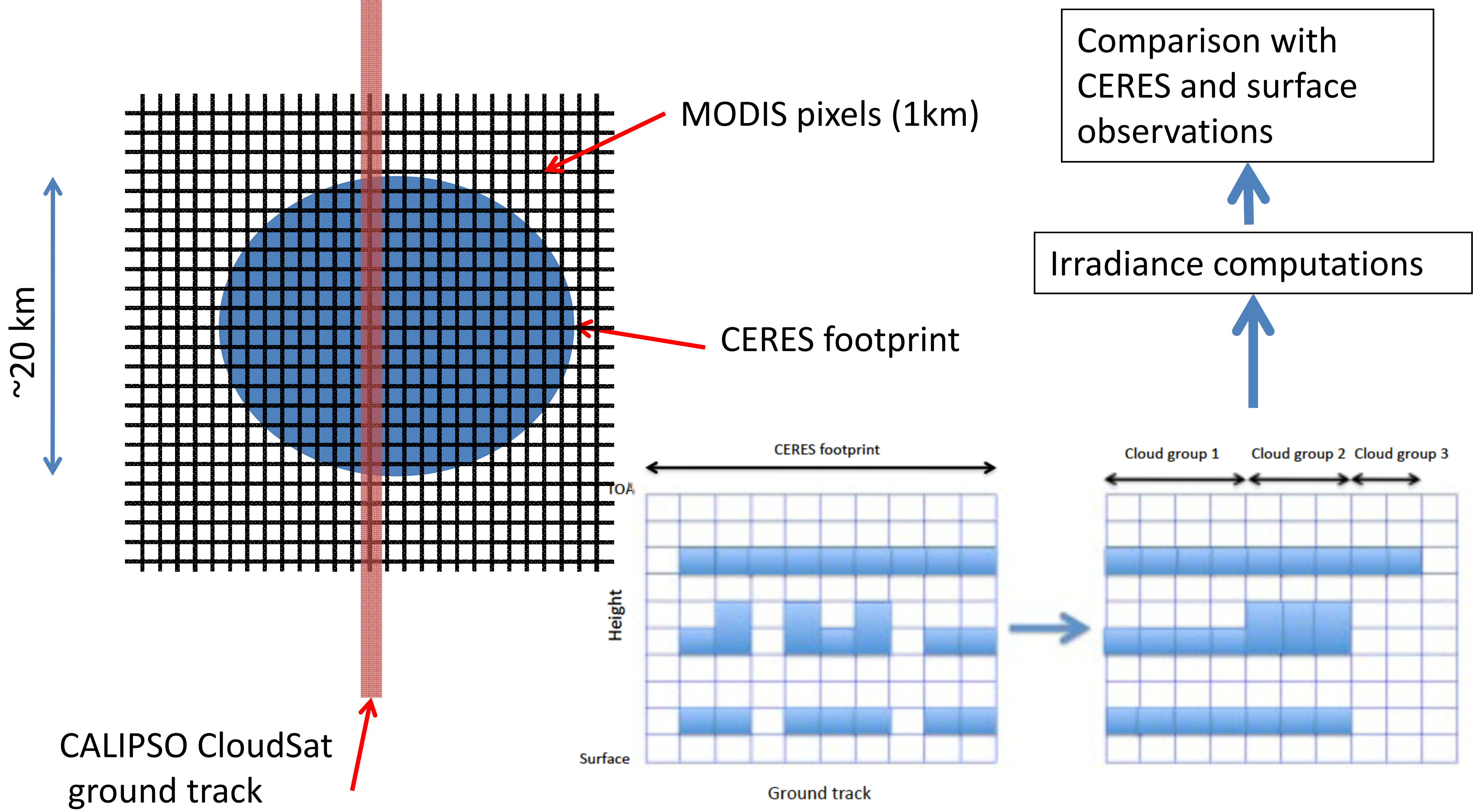
C3M

- Format is similar to the CERES Level 2 data product SSF.
  - Share some inputs with CERES data products (T and Q, snow/ice map, aerosol transport model).
  - Heavily relies on CERES experiences and resources.
- Provides cloud and aerosol properties that are likely to be used in research.
  - Over 400 variables
  - Including not just best values (properties derived from passive and active sensors, multiple irradiances)
  - Mean values over the ground track and full footprint are kept
  - Including retrieval from an enhanced MODIS cloud algorithm (uses CLAIPSO CloudSat information)
- Make the origin transparent as much as possible
  - Cloud top and base source flags
  - Maintain original data quality (e.g. spatial resolution) as much as possible
  - Keep original quality flags as much as possible
- Try to provide all inputs used in irradiance profile computations
  - How we compute irradiance profiles is transparent.
  - User can reproduce our irradiance profile computations
  - Some variables and flags are included for our QC purpose (e.g. irradiance model source flag)

CERES Data Processing Flow



Merging strategy and irradiance computations



CERES point spread function is used to reduce FOV size difference
Same cloud profiles are grouped for the independent column approximation
i.e. horizontal resolution of CALIPSO and CloudSat products is maintained

Input data

MODIS (retrievals are done by the CERES cloud algorithm)

MAC021S1.AYYYYJDY.HHMM.*.hdf, MAC_GEO

MAC03S1.AYYYYJDY.HHMM.*.hdf

MAC_AEROSOL: MAC04S1.AYYYYJDY.HHMM.*.hdf

CALIPSO

CALIPSO_VFM:CAL_LID_L2_VFM-Prov-V3-01.YYYY-MM-DDTHH-*hdf

CALIPSO_05kmALay:CAL_LID_L2_05kmALay-Prov-V3-01.YYYY-MM-DDTHH-*hdf

CALIPSO_05kmCLay:CAL_LID_L2_05kmCLay-Prov-V3-01.YYYY-MM-DDTHH-*hdf

CALIPSO_05kmCPro:CAL_LID_L2_05kmCPro-Beta-V3-01.YYYY-MM-DDTHH-*hdf

CloudSat

CLOUDSAT_CLDCLASS:YYYYJDY*_CS_2B-CLDCLASS_GRANULE_P_R04_E00.hdf

CLOUDSAT_CWC-RO:YYYJDY*_CS_2B-CWC-RO_GRANULE_P_R04_E01.hdf

CERES

SSF, CRS

Cloud properties

Calipso cloud mask	CALIPSO VFM
CloudSat cloud mask	CloudSat CLDCLASS
C05kmCPro_ExtinCoef532	CALIPSO 5 km cloud profile
C05kmCLay_ExtinctionQC_532	CALIPSO 5 km layer
C05kmCLay_CAD_Score	CALIPSO 5 km layer
C05kmCLay_Layer_Top_Altitude	CALIPSO 5 km layer
C05kmCLay_Layer_Base_Altitude	CALIPSO 5 km layer
Cloud class	CloudSat CLDCLASS
Precp flag	CloudSat CLDCLASS
ROliqEffRadius	CloudSat CWC-RO
ROiceEffRadius	CloudSat CWC-RO
ROliqWatContent	CloudSat CWC-RO
ROliqWatContentUncert	CloudSat CWC-RO
ROiceWatContent	CloudSat CWC-RO
ROiceWatContentUncert	CloudSat CWC-RO

Aerosol properties

A05kmALay_OptDepth532
A05kmALay_OptDepthUncer532
A05kmALay_OptDepth1064
A05kmALay_OptDepthUncer1064
A05kmALay_Layer_Top_Altitude
A05kmALay_Layer_Base_Altitude
A05kmALay_Relative_Humidity
A05kmALay_ExtinctionQC_532
A05kmALay_ExtinctionQC_1064
A05kmALay_CAD_Score
A05kmALay_Opacity_Flag
A05kmALay_Horizontal_Averaging
A05kmALay_Number_Layers_Found

All from CALIPSO 5 km aerosol layer product

How C3M is used in NASA

- Evaluation of passive sensor only surface and atmospheric irradiance estimate
- Validation of MODIS retrieval
  - Intermediate pixel level product helps
- Analysis of the effect of scene ID to irradiance derived from ADMs
- Aerosol direct radiative effect analysis (sensitivity study)
- Determine instrument requirements for the CLARREO mission (simulating CLARREO observations with realistic clouds)

Estimating the effect of the scene I.D. error to ADM irradiance estimate (SW)

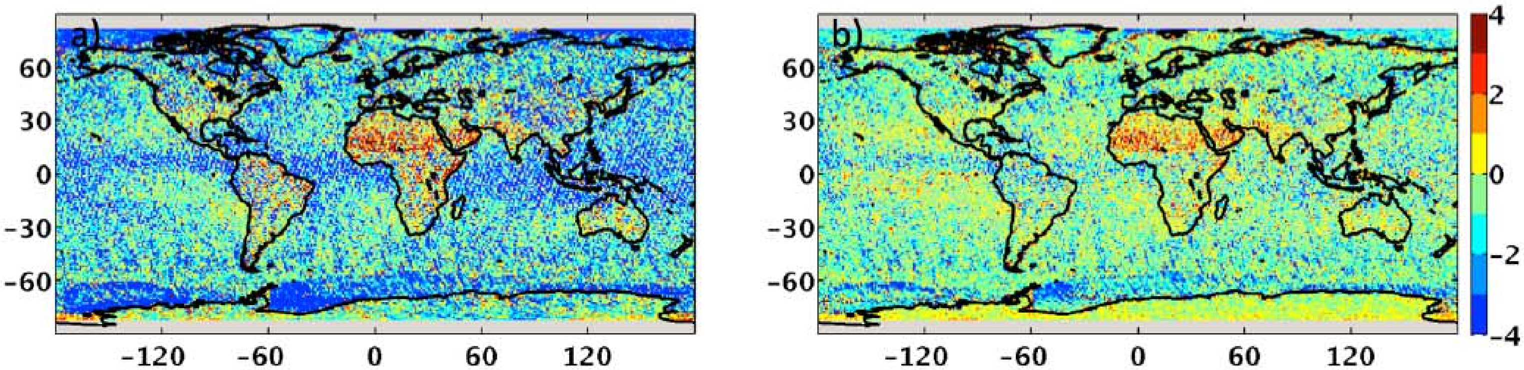


Figure 10. TOA SW flux error ($W m^{-2}$) caused by scene identification uncertainty (standard – enhanced) **(a)** only using near-nadir viewing geometries, **(b)** using extended viewing geometries that are similar to the CERES observations.

Su et al. AMT, 2015

Estimating the effect of the scene I.D. error to ADM irradiance estimate (LW)

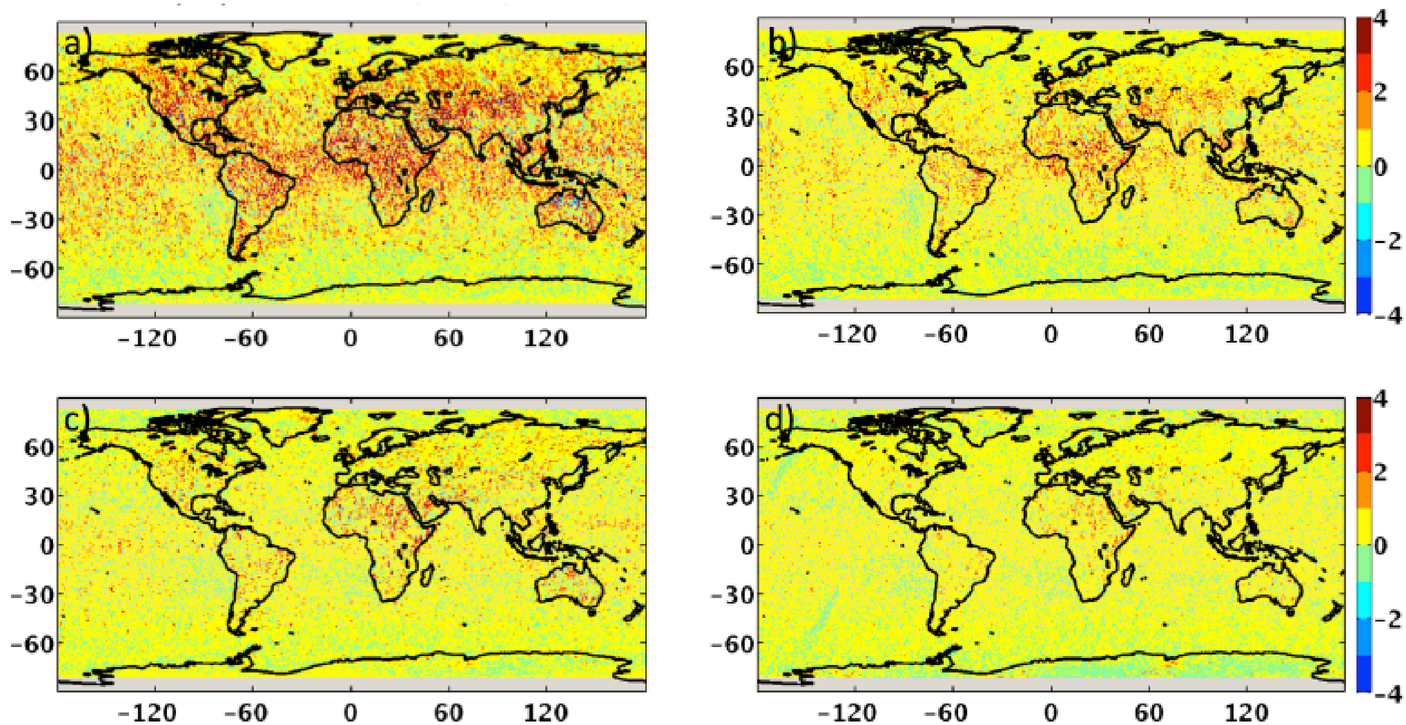


Figure 12. TOA LW flux error ($W m^{-2}$) caused by scene identification uncertainty (standard – enhanced) **(a)** daytime LW flux error only using near-nadir viewing geometries, **(b)** daytime LW flux error using extended viewing geometries that are similar to the CERES observations, **(c)** same as **(a)** but for nighttime LW flux error, **(d)** same as **(b)** but for nighttime LW flux error.

Su et al. AMT, 2015

View zenith angle of CERES instrument

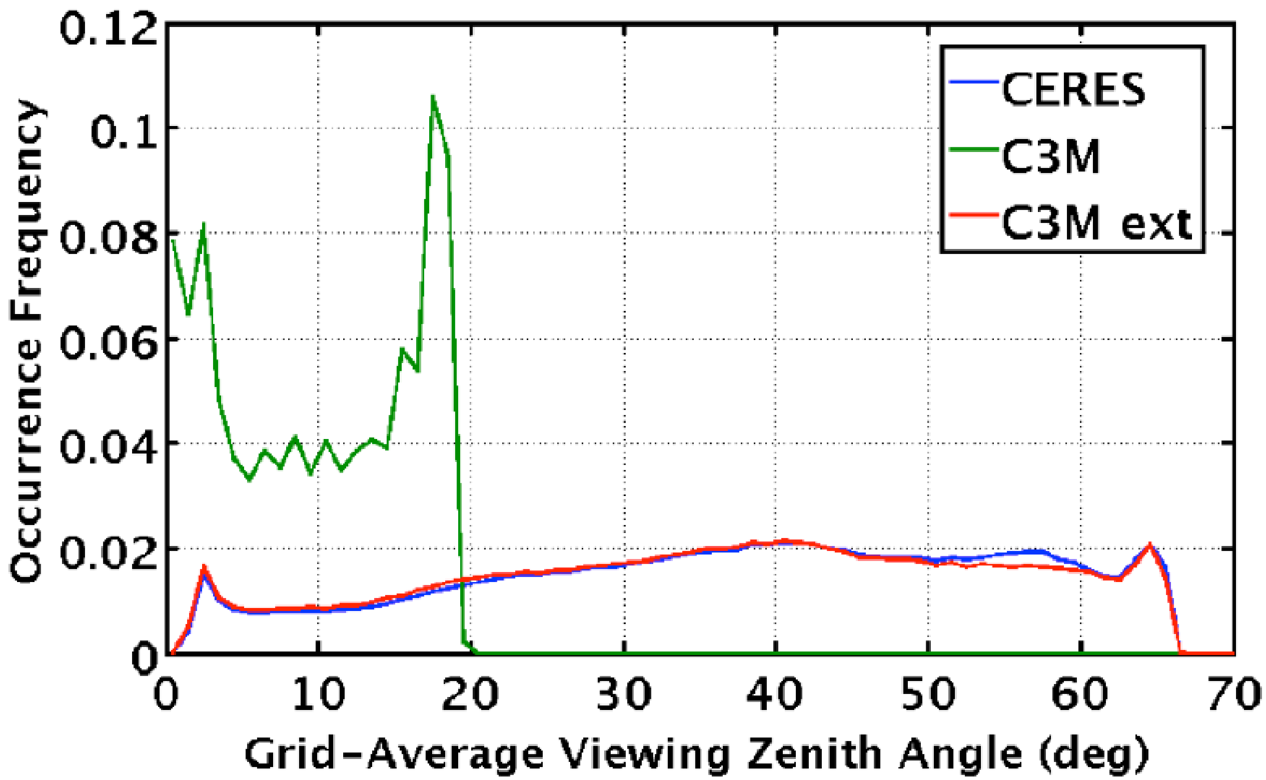
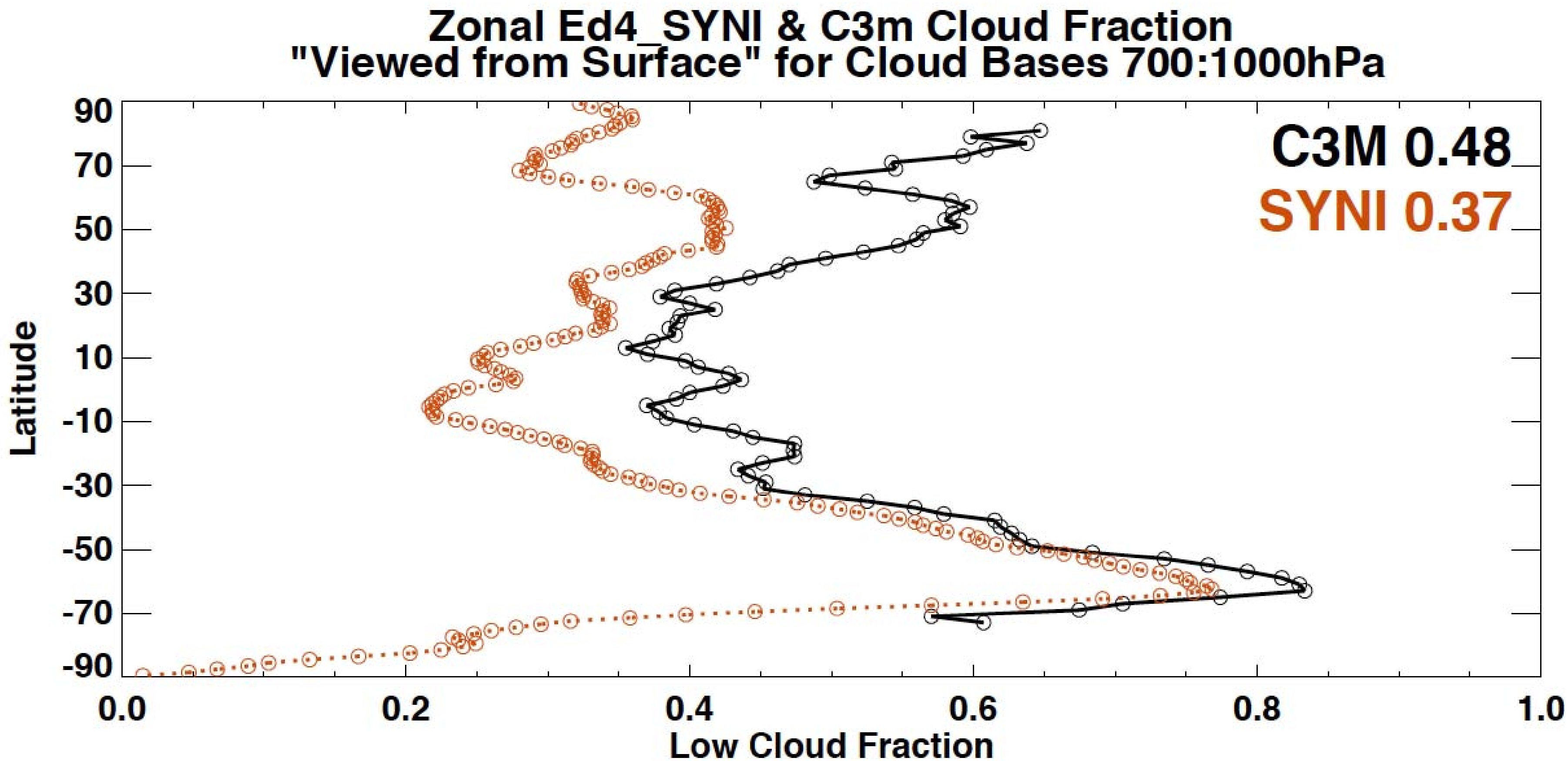


Figure 11. Distributions of grid-averaged viewing zenith angle for CERES data (blue), C3M data (green), and the C3M extended data (red), using data of April 2010.

Su et al. AMT, 2015

Low-level cloud fraction comparison (Jan. 2010)



- Cloud fraction and base height difference will be converted to the downward longwave irradiance change.
- The longwave irradiance change will be used for the bias correction

Boundary layer lapse rates derived from CALIPSO and MODIS

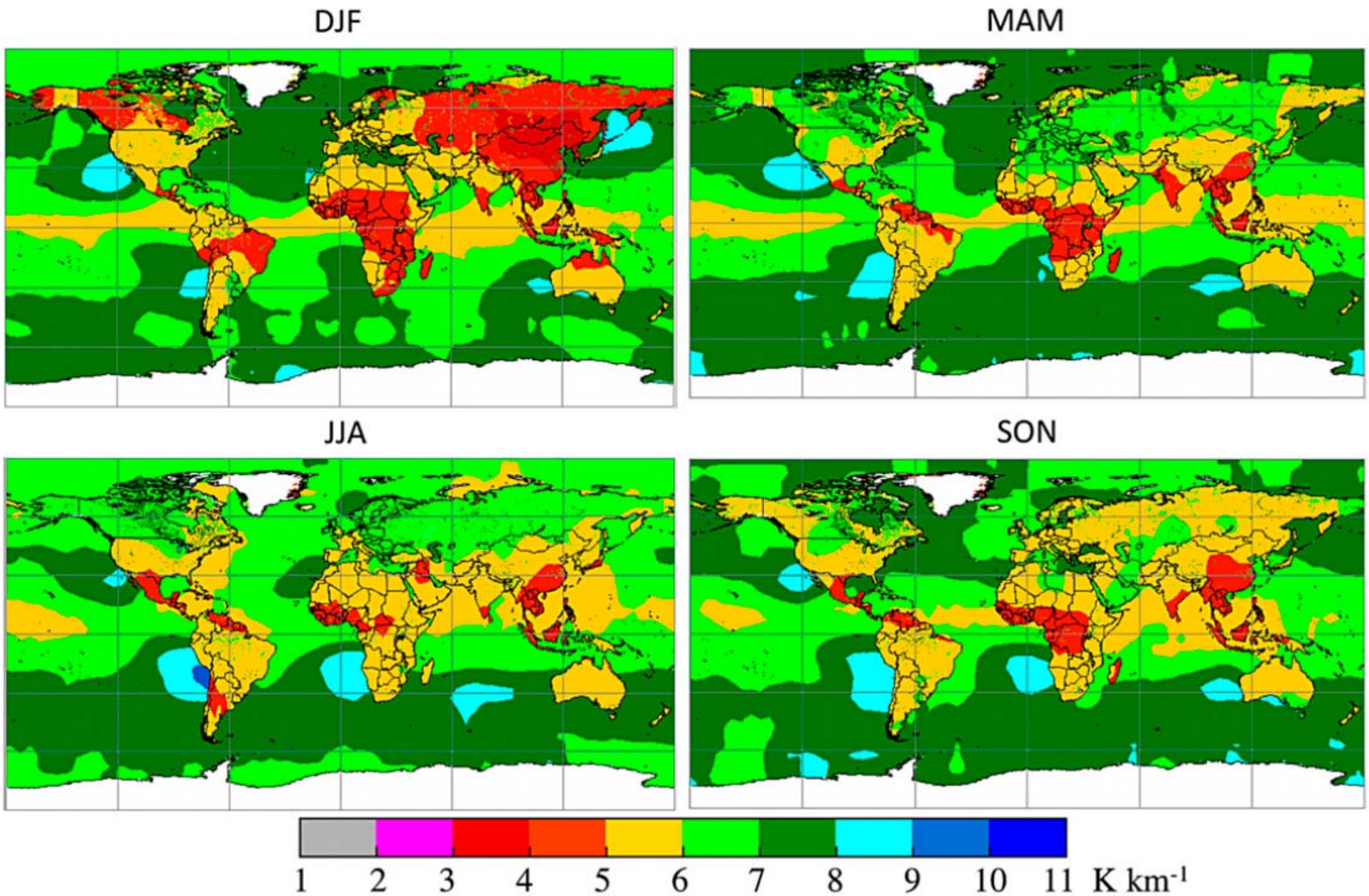


FIG. 6. Daytime boundary layer lapse rates ($K\,km^{-1}$) over snow–ice-free scenes for DJF, MAM, JJA, and SON: July 2006–June 2007 and June 2009–May 2010 (2 yr).

Sun-Mack et al. 2014 JAMC

Atmospheric heating rate

- Starting point is cloud fields derived from MODIS only.
  - Limitation of the passive sensor is known. Active sensors are used to improve the limitation.
- Many if statements
  - If CALIOP retrieval is not available or if CloudSat retrieval is not available etc…
- Heating rates are under utilized perhaps because
  - Radiation is one component (needs latent heat and advection).
  - Covers only nadir view.
  - Diurnal correction is needed.

How C3M is used by others

- Aerosol (indirect effect) and polar studies
- Evaluation of cloud parameterization in a climate model
- Evaluation of passive sensor derived cloud properties
- Use cloud, aerosol, and atmospheric properties provided by C3M, users can compute radiative flux by themselves.

Cloud fraction, LWC, and IWC comparisons

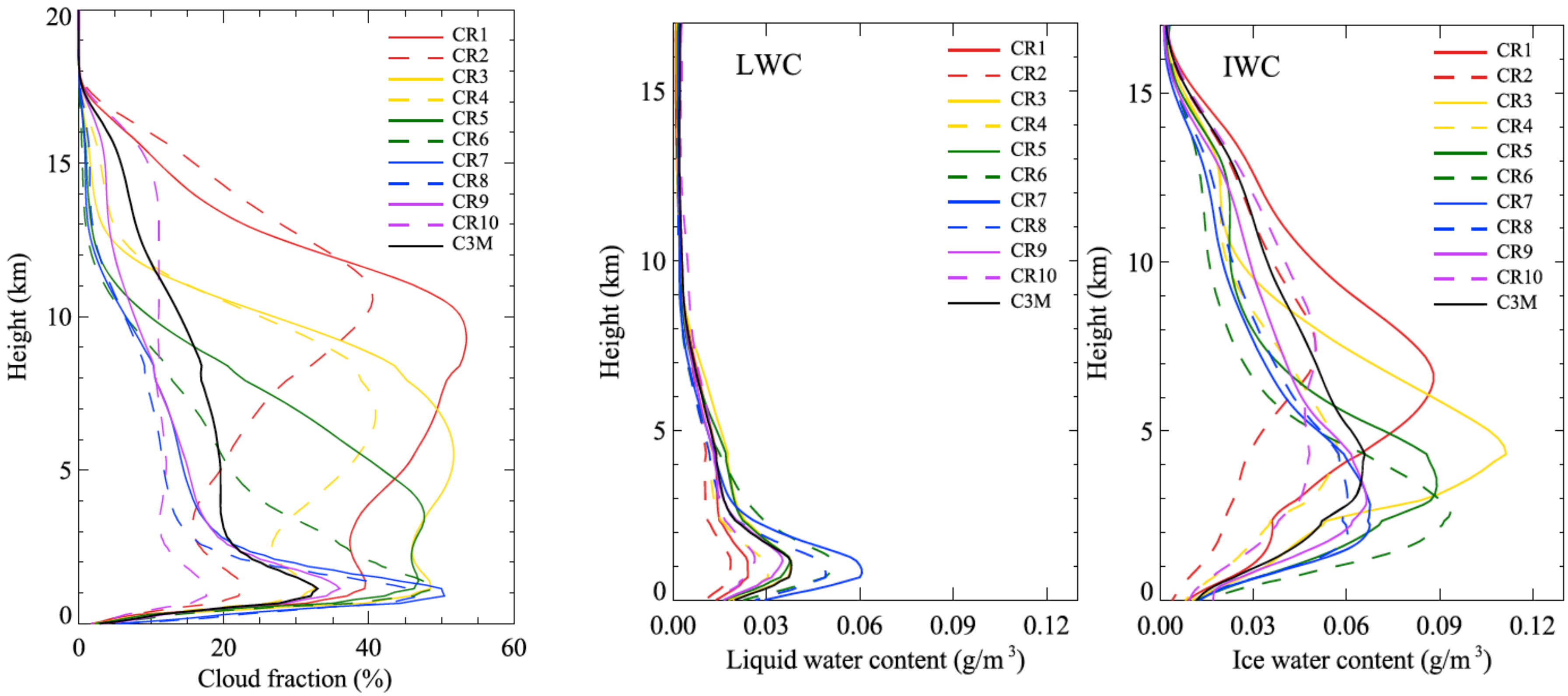


Figure 10. Composites by MODIS-Aqua CR of C3M volumetric cloud fraction profile defined in the text. Also shown is the profile of this quantity averaged across all MODIS-Aqua CRs (curve labeled "C3M").

Oreopoulos et al. 2014 JGR

Aerosol effect on clouds

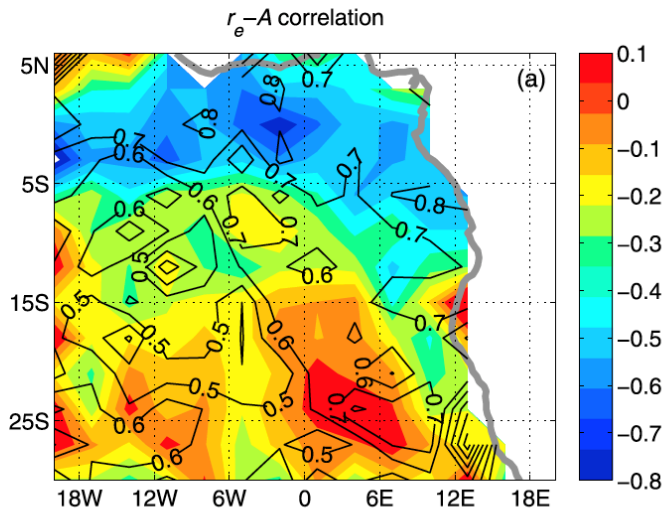


Figure 13. (a) Temporal linear correlation coefficients between r_e and A (colors), and LWP and A (contours). (b) Albedo susceptibility S_R.

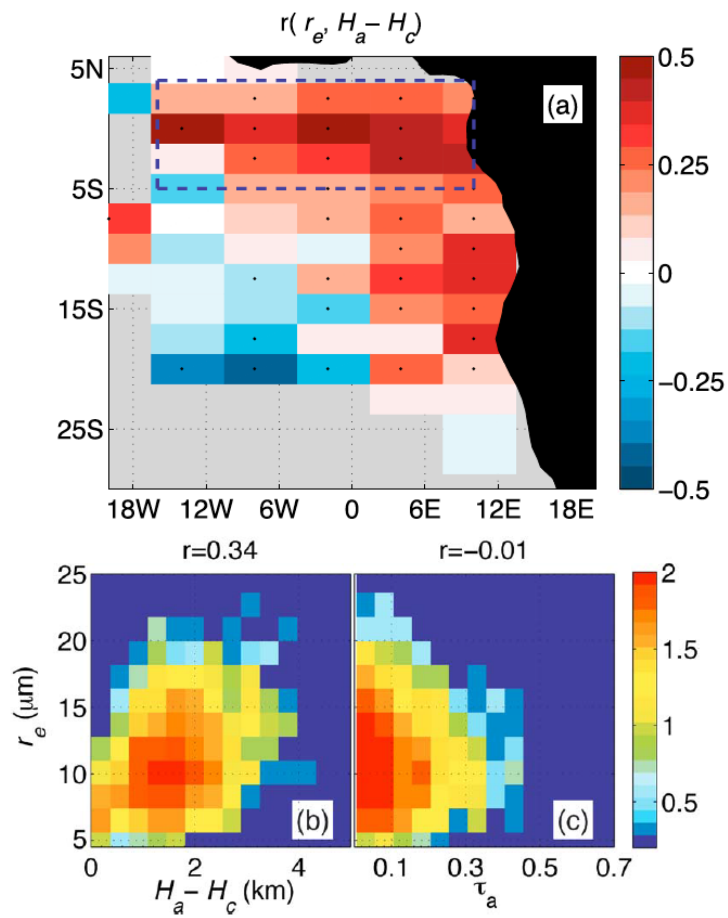


Figure 5. Correlations between aerosol and cloud related quantities. (a) Temporal linear correlation coefficients between r_e and $H_a - H_c$ (ΔH) calculated over 6°×2.5° regions. Values reported for regions with at least 30 samples, and dots are as in Figure 2. (b) Bivariate histogram of $H_a - H_c$ and r_e over the dashed blue rectangle in Figure 5a, colors in ln (number of samples). (c) As in Figure 5b, but for τ_a and r_e. Correlation coefficient r shown at top of Figures 5b and 5c.

Painemal et al. 2014 JGR

Future improvements

- Gridded (Level 3) product
- Lidar horizontal averaging and the signal attenuation level (affect cloud base)
  - Currently 5 km averaging is used. This might be too low for warm boundary layer clouds (need a study).
- Consider using more aerosol type derived from CALIOP
  - Current version only use dusts, all others comes from an aerosol transport model (MATCH)

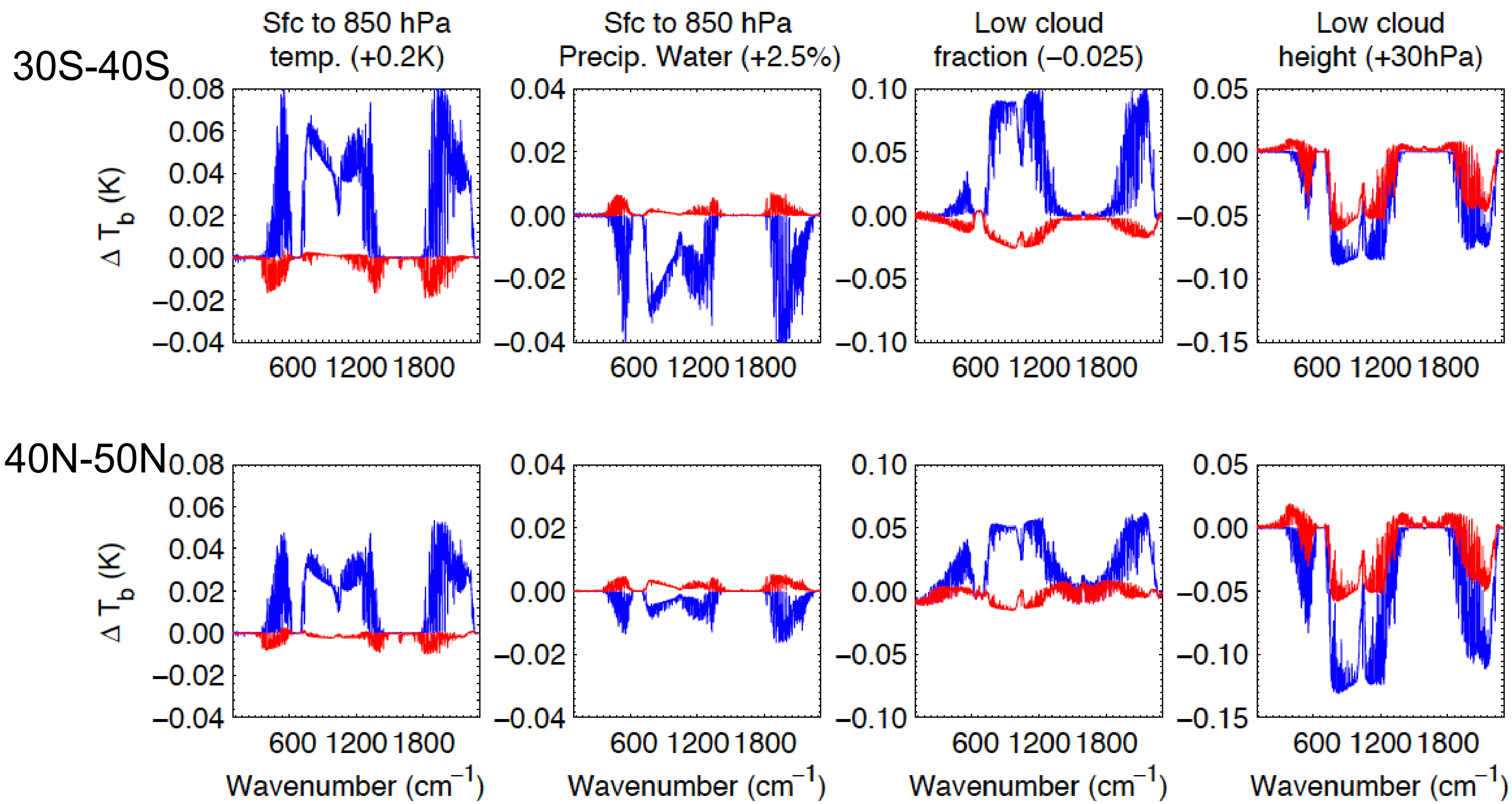
Potential use of active sensor derived cloud fields

- Spectral radiance closure.
- Use spectral fingerprinting and spectral radiance anomalies.
- Derive T and Q deviations from climatological mean.
- This approach might be used to improve T and Q.

MERRA DATA

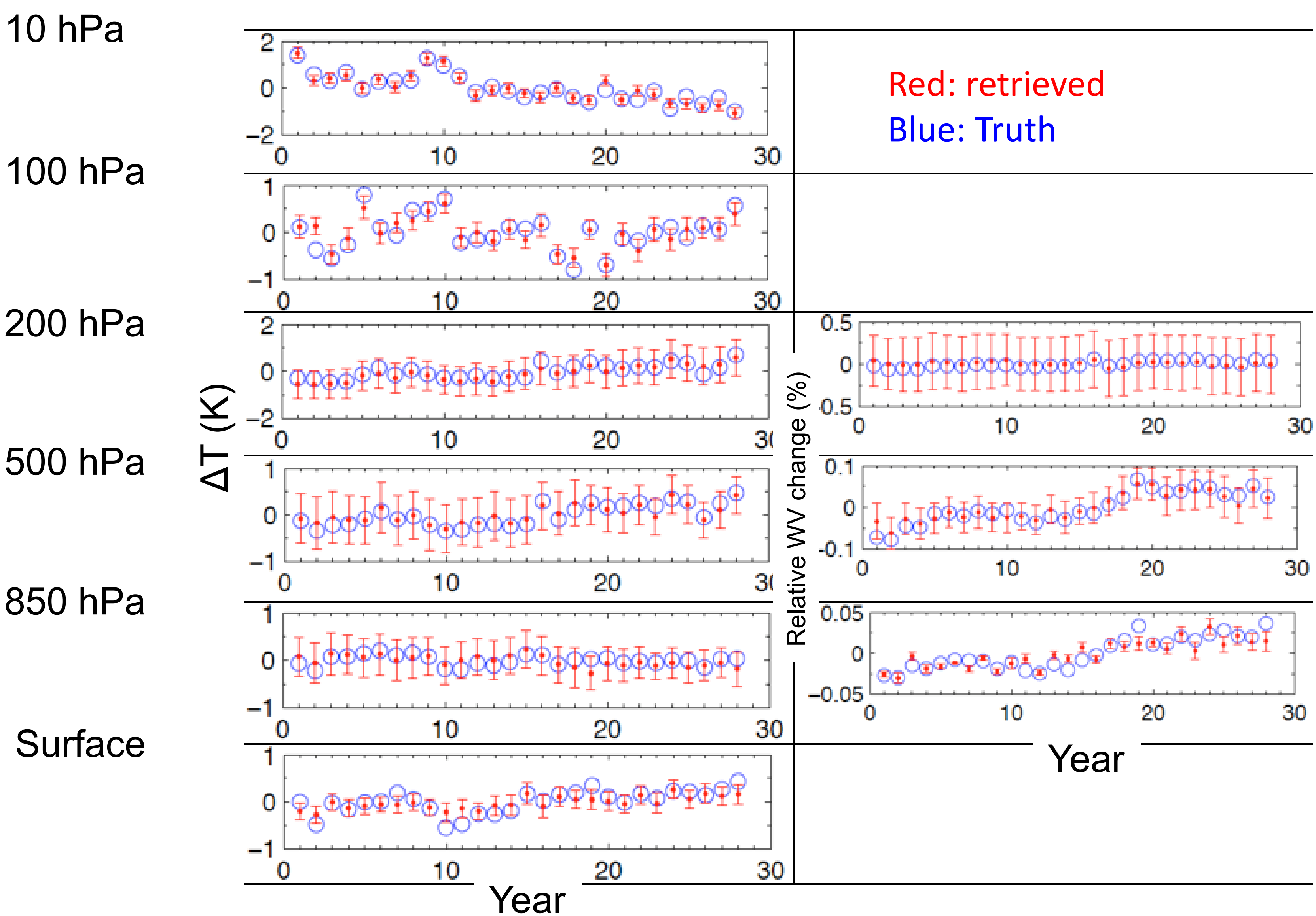
- 1983 – 2010 : 28 years
  - Global (540,361) (0.66 Lon x 0.50 Lat)
  - 6 Hourly:
    - T, Q, O_3 Profiles at 42 vertical levels
  - Hourly :
    - Tskin, T2m, Q2m, Sfc_emiss
    - Random Overlap Cloud Fraction (High, Mid, Low)
    - Cloud Optical Depth (High, Mid, Low)
    - Cloud Pressure (1^{st} layer seen from space)
    - NO Phase, NO Particle Size, Limited Cloud Height info.
      - No Cloud LWC/IWC profile files
    - Clear and Total Sky OLR (MERRA Rt code)
  - Files used :
    - inst6_3d_ana_Np. , tavg1_2d_slv_Nx, tavg1_2d_rad_Nx
    - On /ASDC_archive

Spectral radiance change difference



Spectral radiance change computed by perturbing the monthly 10° zonal mean values indicated at the top of each plot and averaging over a year (blue line). The red line indicates the spectral radiance change computed by perturbing monthly 10° zonal value and averaging over a year minus the change computed by perturbing corresponding instantaneous values sampled by a 90 inclined polar orbit.

Retrieved T and Q anomalies (10° zone of 40° S to 30° S)



Retrieved from all-sky spectral radiance anomalies

Kato et al. 2014 J. Climate